NEMATODE DISEASE of WHEAT and RYE

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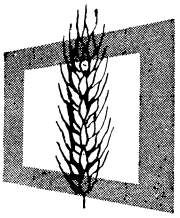

NEMATODE DISEASE of WHEAT and RYE

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The nematode disease [1] of wheat and rye was first reported in the United States in 1909 in California. It was reported later from other States and at times has caused severe losses in some winter wheat areas, especially in the Southeast—Maryland, Virginia, North Carolina, South Carolina, and Georgia.

The disease is caused by tiny eelworms or nematodes that are enclosed in galls found in threshed grain. The disease is easily spread by these galls in seed grain and may be present in other winter-wheat-growing areas where it has not been recognized. It seems desirable, therefore, to describe the symptoms of the disease and the methods effective in controlling it so that it may be readily recognized and promptly eradicated wherever it appears.

DESCRIPTION OF THE DISEASE

Galls in Grain

The presence of the wheat-nematode disease usually is first discovered by finding the hard dark galls in the threshed grain. These galls often are mistaken for cockle seeds, vetch seeds, smut balls, bin-burnt kernels, ergot bodies, or other substances commonly found in threshed grain. Cockle seeds are easily distinguished by their spiny coat and characteristic shape; vetch seeds by their smoothness, uniform color, and roundness; smut balls by their black, dusty contents, fishy odor, and the ease with which they can be crushed between the fingers; and bin-burnt kernels and ergot bodies by their general shape and cross section. Some of these differences are illustrated in figure 1.

The nematode galls from wheat range from one-eighth to three-sixteenths of an inch in length and from one-sixteenth to one-eighth of an inch in width. They are rather dark in color with light-brown tips, and usually are grooved somewhat like a wheat kernel. Many galls vary from the average in size and shape so that sometimes it is difficult to recognize them. Galls from emmer and spelt are similar in size, color, and shape to those from wheat, but galls from rye, as a rule, are smaller, relatively longer, and lighter in color. Galls from certain varieties of spring wheat also differ slightly in shape and color. The disease, however, is not known to occur in areas where only spring wheat is grown.

Seedling Symptoms

If wheat seed containing nematode galls is sown in clean soil, or if seed is sown in soil infested from a diseased crop of the previous year,

[1] Caused by the nematode *Anguina tritici* (Steinbuch) Filipjev, formerly referred to as *Tylenchus tritici.*

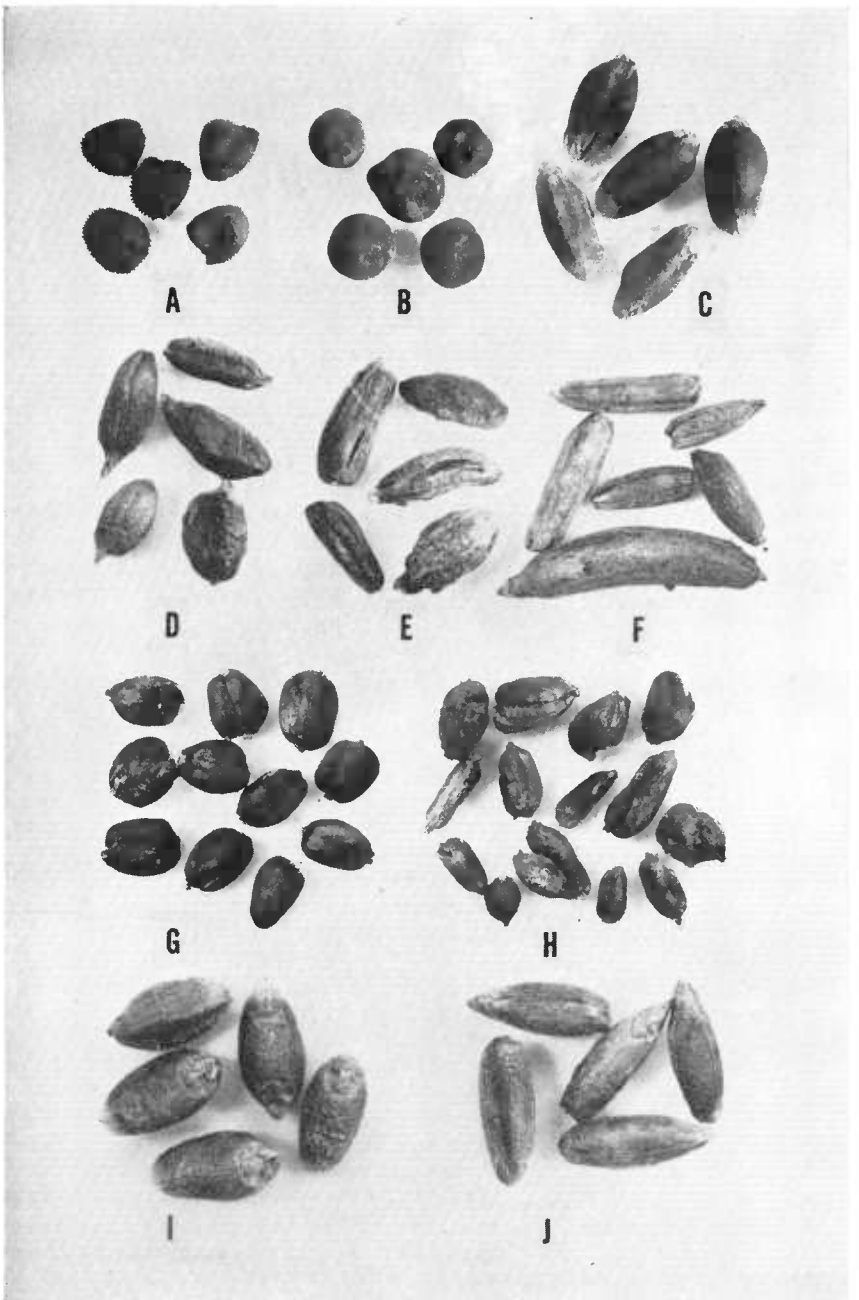

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FIGURE 1.—Comparison of nematode galls with normal kernels of wheat and rye and with impurities commonly found in threshed grain. (Enlarged three times.) Note the comparative uniformity in size and form of the galls from wheat, and the variation in size and form of the galls from rye. *A*, Cockle seed; *B*, vetch seed; *C*, bin-burnt wheat kernels; *D*, bunt balls; *E*, ergot sclerotia from wheat; *F*, ergot sclerotia from rye; *G*, nematode galls from wheat; *H*, nematode galls from rye; *I*, wheat kernels; *J*, rye kernels.

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FIGURE 2.—Wheat seedlings attacked by nematodes. Note the wrinkled leaves with curled edges and the emerging leaves tightly rolled.

many of the seedlings will show the rolling, twisting, curling, or wrinkling of the leaves and other plant distortions characteristic of the wheat-nematode disease (fig. 2). The rolled or curled leaf often encloses the next emerging leaf or the awns of the emerging head. This causes the plant to become badly distorted, and causes the stem to bend, as shown in figure 3. The stem may be enlarged near the base; frequently it is bent, and usually it is more or less stunted. In some plants only one or two culms may be affected, while in others all may be diseased.

Head Symptoms

As the plant approaches maturity, the earlier symptoms become less evident unless the plant is very severely diseased, in which case it either dies before heading or bears a very imperfect and badly diseased head.

Diseased heads usually are shorter and thicker than the healthy ones, and the glumes are spread apart by the nematode galls, which

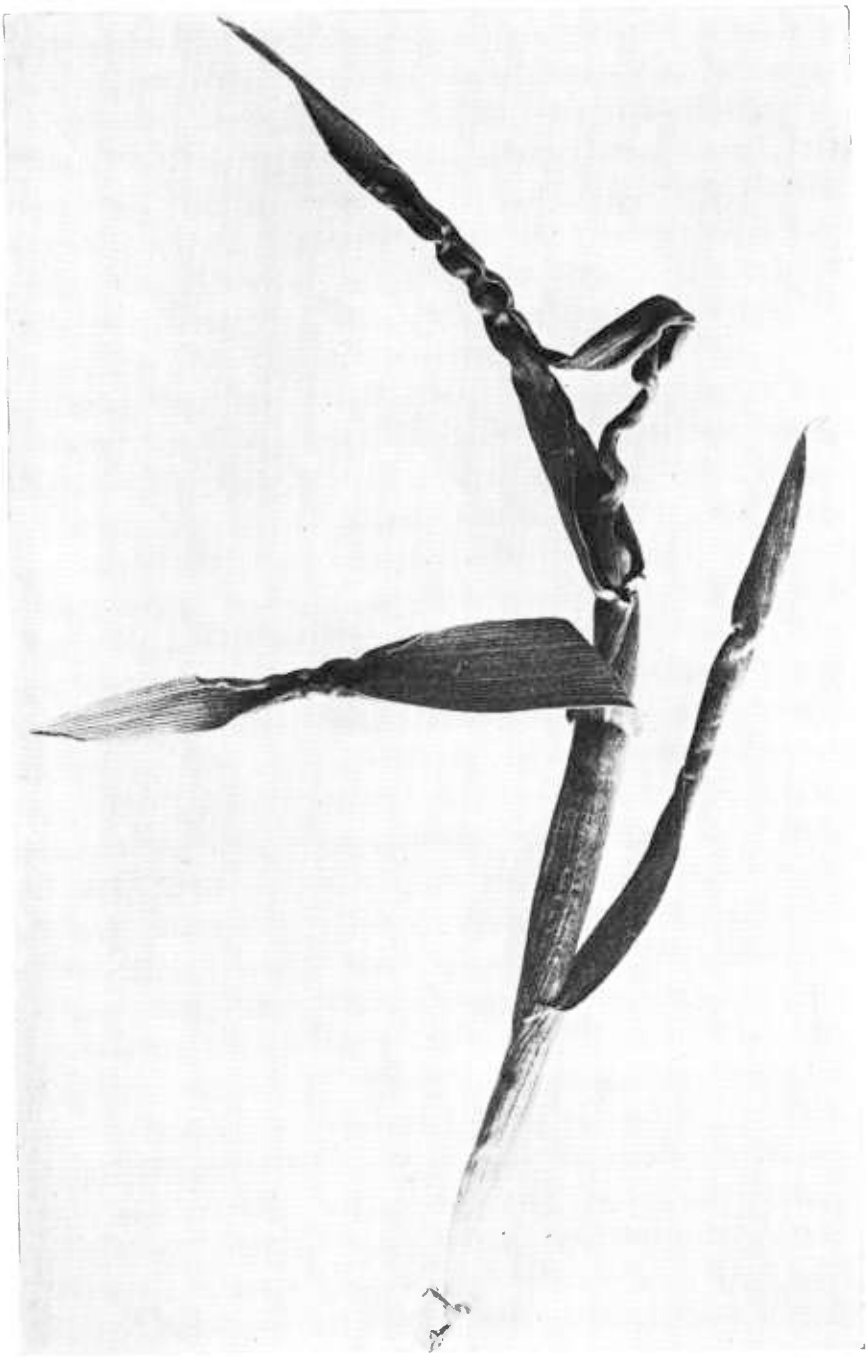

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FIGURE 3.—Wheat seedling attacked by nematodes. Note the emerging leaf tightly held by the curling of the older leaf enclosing it.

replace the kernels (fig. 4). Frequently, several galls are found in place of a single kernel (fig. 5). At first, these galls are of a shining green color, but as the heads ripen, the galls in wheat turn dark brown or black, and those in rye become straw colored. Some heads contain only galls, while others contain both galls and kernels. It is not uncommon to find a single gall in an otherwise healthy head or a single sound kernel in a badly diseased head. Partially diseased heads often are hard to distinguish from healthy heads. Diseased heads remain green longer than do healthy heads, and at maturity the glumes often assume a dirty brownish color. The galls shatter out of the heads

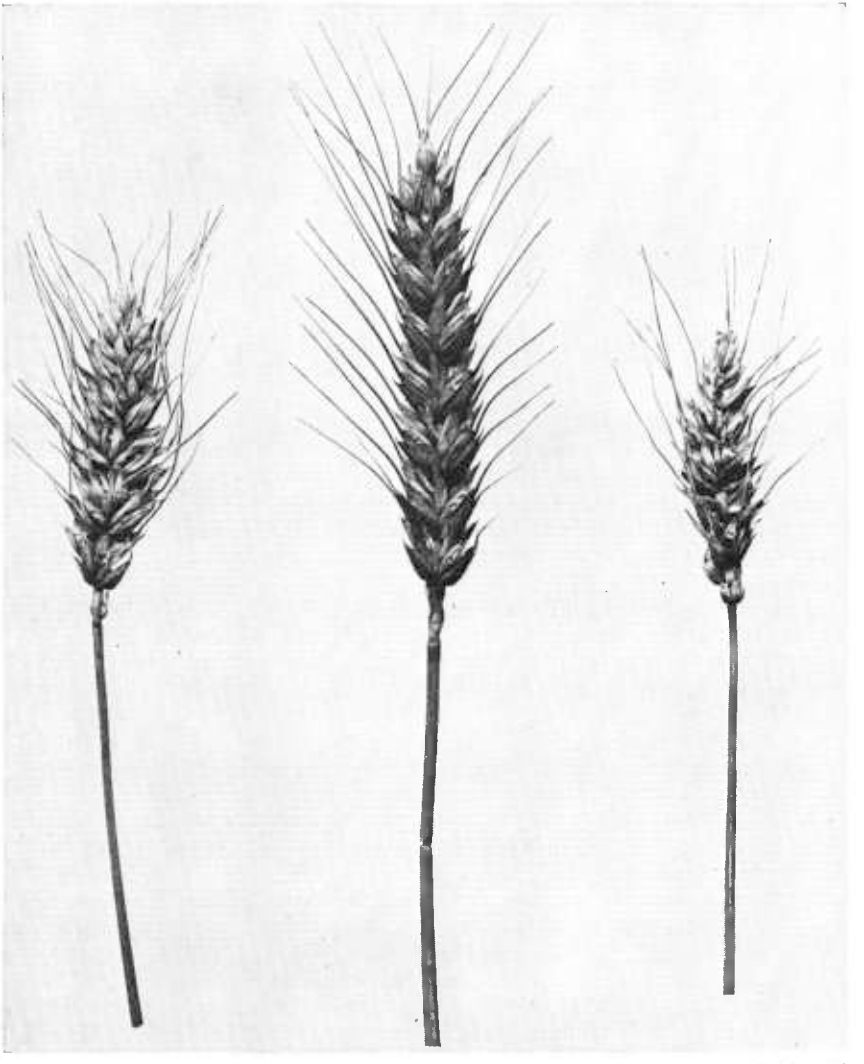

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FIGURE 4.—Healthy head of wheat shown between two nematode-infested heads. In the diseased heads note the spreading chaff, the distorted awns, and the dark galls in place of normal wheat kernels. (About three-fourths natural size.)

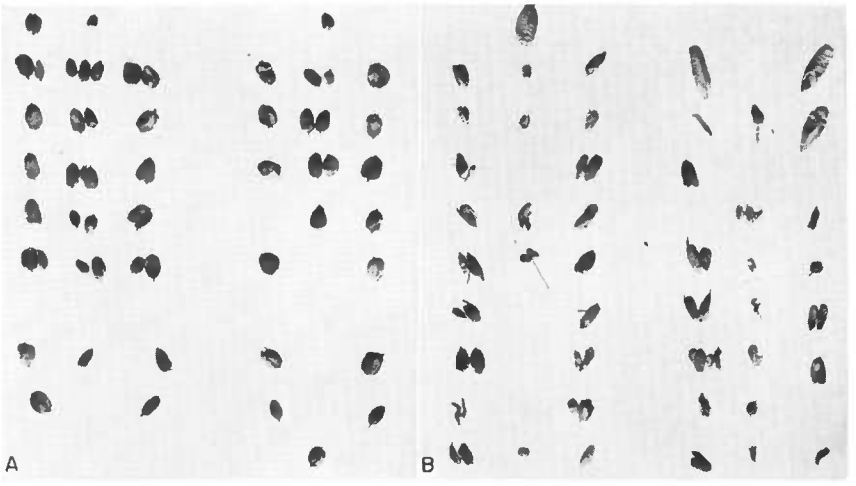

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FIGURE 5.—Nematode galls arranged as found in the different spikelets on opposite sides of (*A*) a head of wheat, and (*B*) a head of rye.

more readily than do the kernels, and during harvest many galls fall to the ground, thus infesting the soil for a subsequent crop if wheat is sown in the same field in the fall.

CAUSE OF THE DISEASE

The galls commonly found in infested grain contain a dry, dormant mass of tiny eel-like nematodes, each about one twenty-fifth of an inch long. A cross section of a gall, much enlarged, is shown in figure 6. If the galls are placed in water for a few hours and then carefully cut open, the nematodes absorb water, gradually revive, and begin a rapid whipping movement that may be observed under a low-power microscope (fig. 7).

In moist soil, the galls soon soften and collapse, and the nematodes, revived by the absorption of water, escape into the soil, where they attack young wheat or rye seedlings. They get between the leaf sheaths and gather about the growing point. Here they remain until the wheat flowers begin to form. Then, presumably, they pierce and enter the developing kernels and cause the formation of galls in place of normal kernels. Occasionally they also invade stamens or ordinary leaf cells to form small galls.

Within these newly formed galls the nematodes develop into mature male and female adults (fig. 8). They mate, after which the females lay the fertilized eggs, and both adults die. One female may produce as many as 2,000 eggs. Since there usually are 5 to 7 or more females in one gall, each gall may contain from 10,000 to 20,000 or more eggs. The eggs first develop into fragile, transparent, thread-like, first-stage larvae, about one-half millimeter (one fiftieth of an inch) in length. These larvae soon develop into second-stage larvae, which are nearly twice as long and more hardy. When the plant matures these larvae go into the dormant stage previously mentioned. In this condition they may remain alive for 25 years or more if the galls are stored in a cool, dry place. Under conditions of high humidity, however, they may not survive for more than 8 or 9 years.

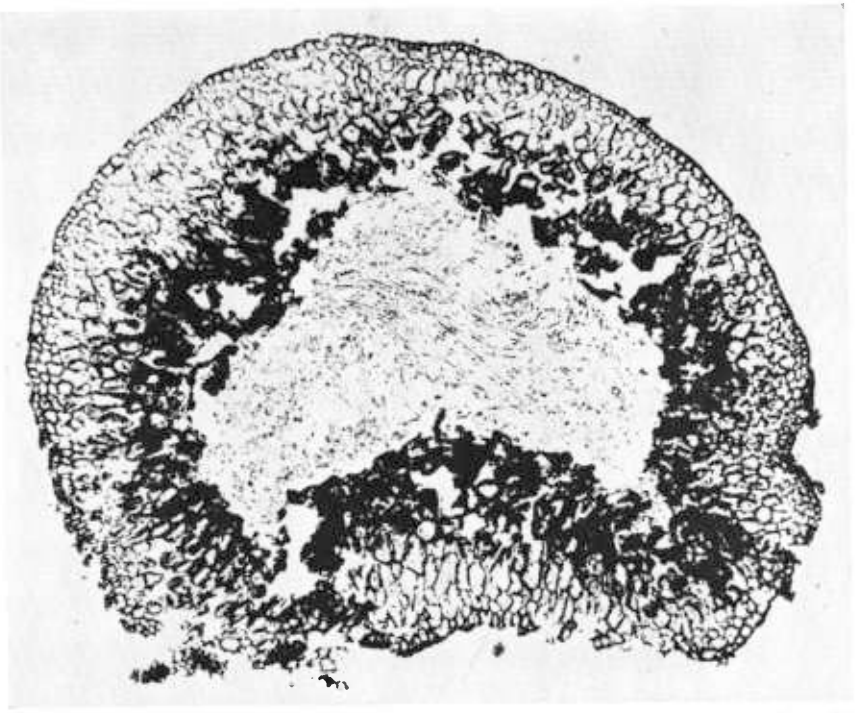

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FIGURE 6.—Cross section of a nematode gall, magnified 35 times, showing the thick wall surrounding the white mass of dormant nematodes.

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FIGURE 7.—Nematodes taken from a gall, placed in water, and photographed through a microscope that magnified them about 30 times. In water, the nematodes move actively with an eel-like motion; therefore, they are often called eelworms.

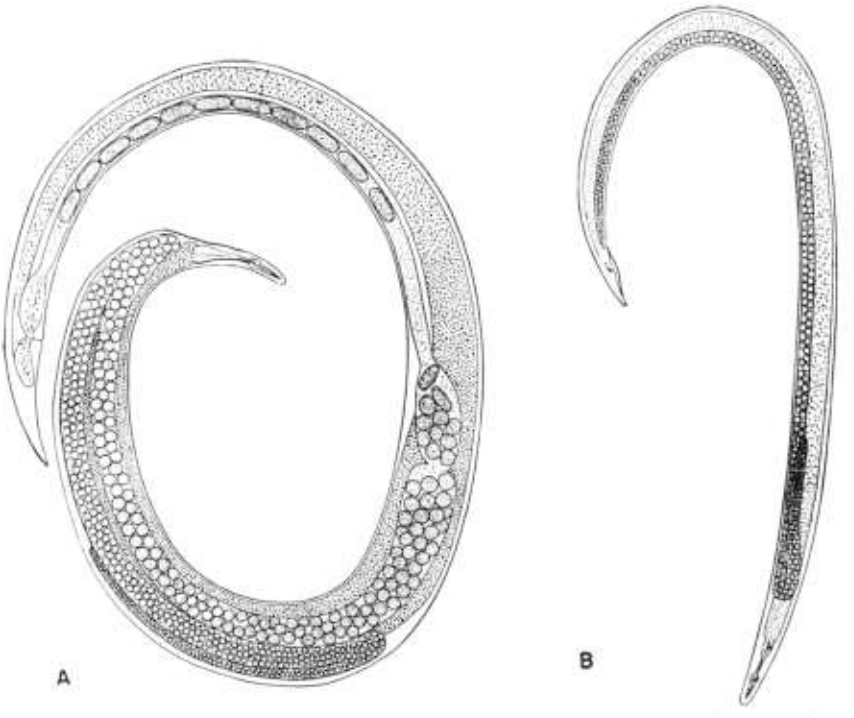

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FIGURE 8.—Mature nematodes. *A*, Female in egg-laying stage; *B*, male. (Greatly enlarged.)

CROPS ATTACKED

Wheat and rye are the principal crops that are injured by the wheat-nematode disease, but emmer and spelt also are susceptible. Oat plants are attacked to some extent in the seedling stage (fig. 9) but no galls have been found in the mature plants. All barley varieties tested seemed to be immune with the exception of Hansee Hulless, which produced a few small, imperfect galls (fig. 10). One species of *Aegilops*, a wheat relative was found to be highly susceptible (fig. 11). So far as known, other grasses are not susceptible.

GEOGRAPHIC DISTRIBUTION

The wheat-nematode disease has been reported from every continent. In Europe it has been found in France, Germany, Austria, Hungary, Switzerland, Italy, Sweden, Holland, and England. In some of these countries it caused severe losses before effective control measures were adopted. In South America it was reported from Brazil, and in Asia it has caused considerable losses in China, India, and Pakistan. Galls have been found also in seed from Russian Turkestan.

The disease was first found in the United States in 1909 near Modesto, Calif., and Oldfields, W. Va. Later in 1909, reports of infested seed were received from New York and Georgia. The disease has been found also in North and South Carolina, Virginia, and Maryland.

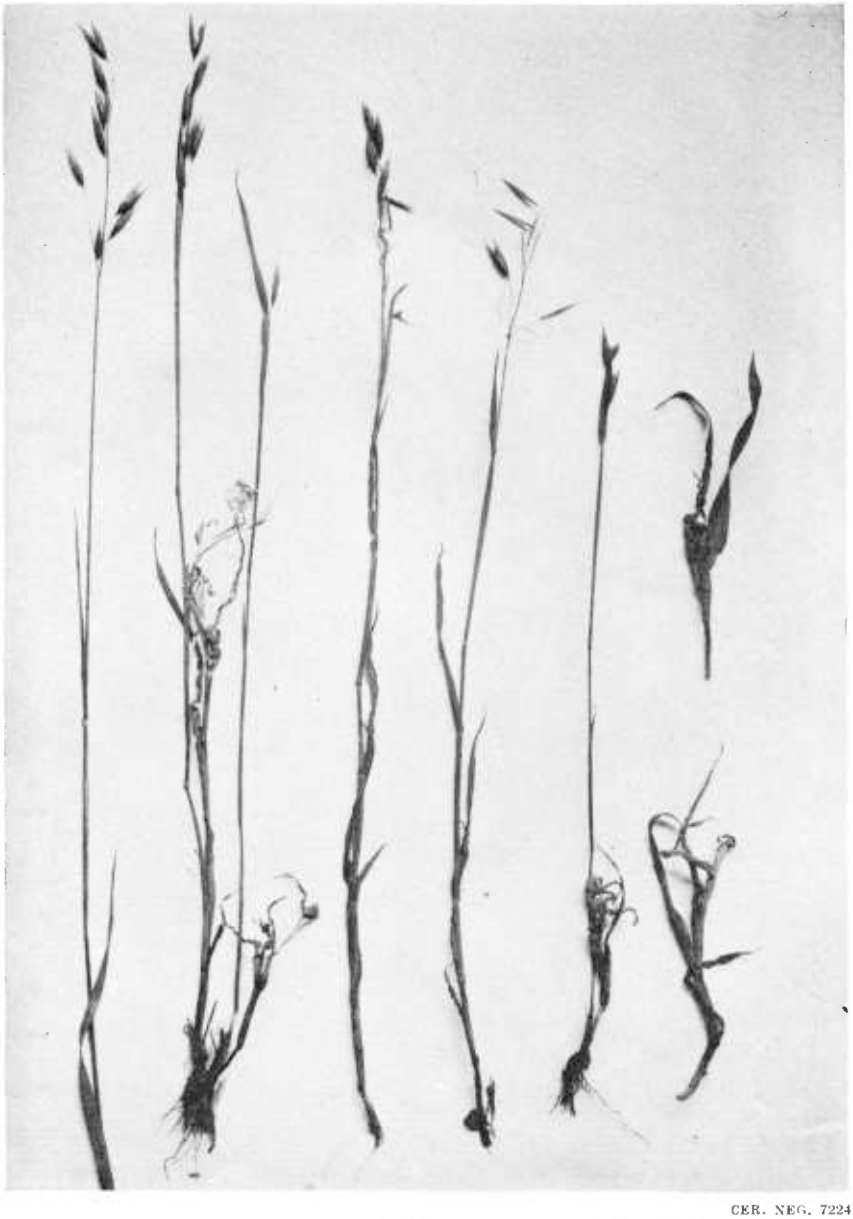

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FIGURE 9.—Oat plants invaded by wheat nematodes. Galls were not found in the panicles although some plants were severly deformed.

The most severe outbreak of the disease in the United States occurred in Virginia in 1918 as a result of continuous wheat culture without rotation, in response to the campaign to "Raise more wheat and win the war." Many fields were so severely infested they were not harvested. In recent years crop rotation and the use of clean seed have eliminated the disease in many areas where it once was troublesome.

CER. NEG. 273

FIGURE 10.—Hansee Hulless barley infested by wheat nematodes.

HOW THE DISEASE SPREADS

The chief way the disease is spread any distance is by galls in the seed grain. Straw from an infected crop also may spread the disease to distant fields, as many of the galls are blown into the straw at threshing time.

Threshing machines and combines may spread the disease from one farm to another. This was demonstrated in one locality in Jackson County, Ga., where, for years, the disease occurred only on farms in a certain "threshing ring."

In the infested regions, the screenings removed from wheat at the mill or elevator usually are taken back to the farm to be fed to stock or poultry. Experiments have shown that the disease is not spread to the fields by the manure of farm animals that have eaten galls, but by the uneaten galls in the litter. An example of this is shown in figure 12. In this case, chickens were fed screenings containing a high percentage of nematode galls. As chickens do not relish these galls, most of them remained uneaten and later, along with the litter, were spread by means of a manure spreader on a strip of land across

CER. NEG. 2437

FIGURE 11.—*Aegilops ventricosa*, a grass-wheat relative, severely injured by wheat nematodes. Normal head at left.

a field that was later sown to winter wheat. In the spring it was observed that the wheat in this strip was stunted and much of it appeared to have been winterkilled. The plants that survived were badly infected by the nematode disease.

Experiments have shown that, in the soil, the nematodes can travel only about 15 inches by their own efforts. Therefore, wheat or rye can be grown safely on clean soil fairly close to infested soil if cross cultivation is not practiced. However, heavy rains may wash some of the infested soil down a slope to nearby clean land and thus spread

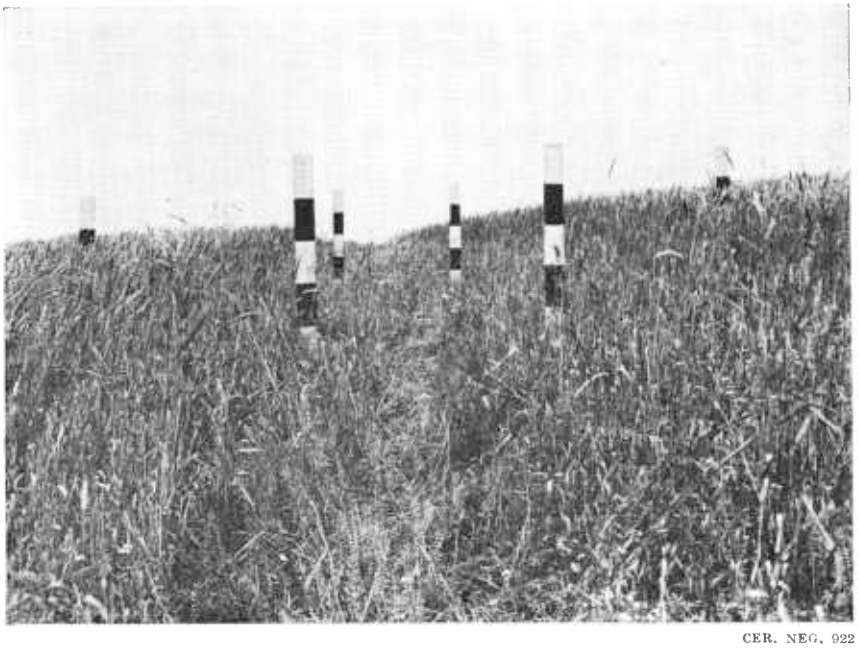

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FIGURE 12.—A strip across a field of winter wheat showing where manure and litter, badly infested with nematode galls, had been applied before sowing. All six stakes, similarly marked, were driven so that each projected 5 feet above the ground. In the center, where the infestation was most severe, the plants were either killed or badly stunted, as shown by the center stakes, 4 feet of which are visible, as compared with the outer stakes, which are almost hidden by the tall, healthy grain.

the disease. The nematodes can travel upward in the soil about a foot, so that deep plowing will not eradicate the pest on infested land.

LOSSES DUE TO THE DISEASE

Since the wheat-nematode disease occurs at present in only a few States, none of which produce a very large portion of the Nation's wheat and rye, the loss caused by the disease in the country as a whole is relatively small. Losses to individual farmers, however, can be and sometimes are very severe. The percentage of galls found in the threshed grain is not a true indication of the total crop loss because much of the damage is done in the seedling stage. Furthermore, many of the galls do not appear in the threshed grain, but are blown out with the straw and screenings at threshing time. The loss in an infested field may be determined more accurately by comparing the yield per acre with that of a nearby uninfested field sown to the same seed and under similar conditions of soil, fertility, and drainage. By this method it was found that losses often ranged as high as 65 percent in rye and 50 percent in wheat.

Several varieties of spring wheat grown from seed artificially infested with galls from winter wheat yielded practically no grain. In addition, the infested plants were badly stunted (fig. 13). These results indicate that the nematode disease would be extremely destructive in a spring-wheat area if infested seed were sown.

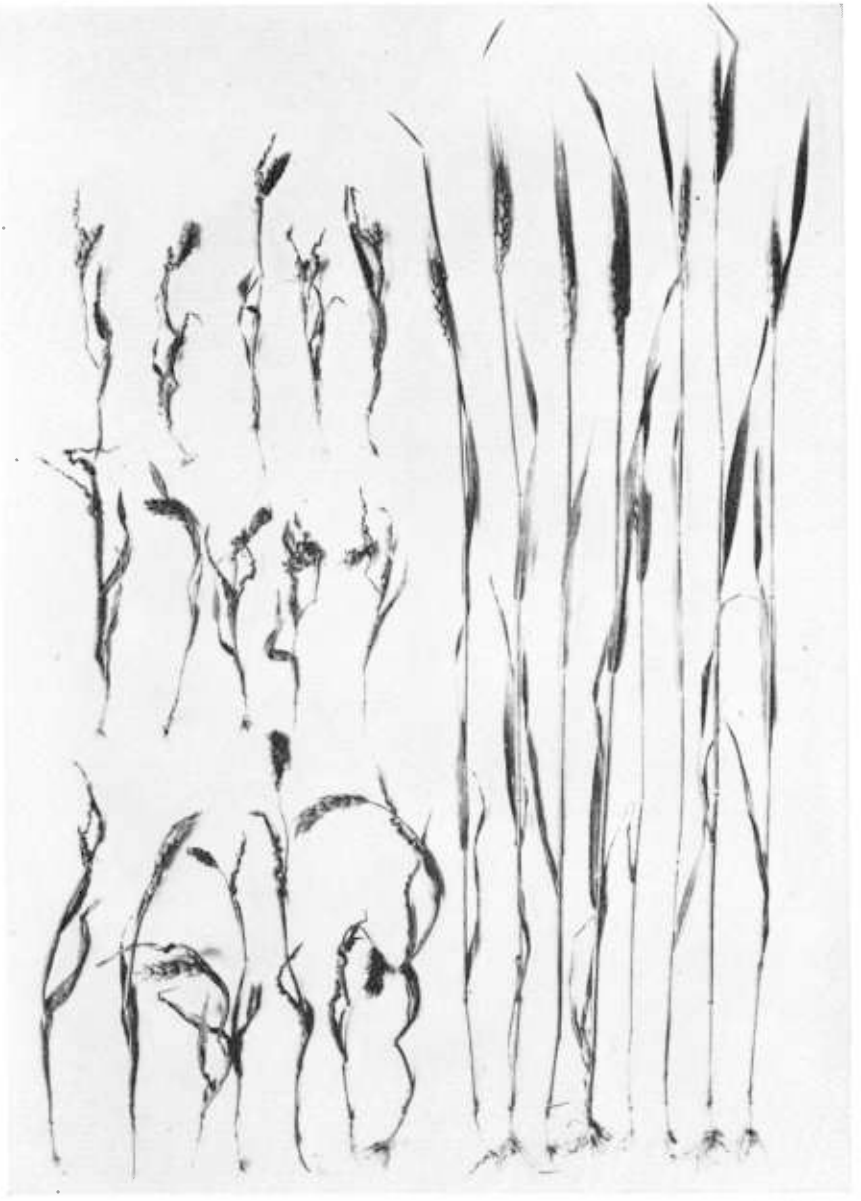

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FIGURE 13.—Effect of nematodes on Prelude spring wheat, sown in artificially infested soil. Note extreme dwarfing and distortion of plants in comparison with plants grown in uninfested soil.

CONTROL OF THE DISEASE

The nematode disease of wheat and rye may be effectively prevented by sowing only clean seed (seed not infested with galls) in clean (uninfested) soil. No satisfactory resistant varieties of wheat or rye are known. Infested soil should not be sown to wheat or rye for one year.

Clean Seed

Only seed of adapted varieties of wheat and rye, free from nematode galls, should be sown. If the past year's seed is infested, it is best to dispose of it and obtain seed that is free from galls. If such seed cannot be obtained, or if the infested seed on hand is a particularly valuable lot that cannot be readily replaced, the galls may be separated from the grain by floating them out in a salt brine as follows: Dissolve common salt in water to make a 20-percent solution—8 pounds of salt to each 5 gallons of water—in a small tank or barrel. After carefully cleaning the seed to remove chaff, light inferior kernels, and weed seeds, pour the infested seed slowly into the salt solution, a peck or less at a time, while stirring the solution vigorously. The sound kernels will sink while the nematode galls, light worthless kernels, some weed seeds, and trash will float and may be skimmed off with a strainer. This material should be boiled, burned, or buried.

Some galls will be carried to the bottom of the barrel with the grain; therefore, the grain should be stirred repeatedly after each skimming to permit these galls to rise to the surface and be skimmed off.

The salt brine should be drained off into another barrel through a screen and the grain thoroughly rinsed several times in fresh water to remove every trace of salt. If the salt is not removed, it will injure germination.

The wet grain should be spread out in a thin layer on a floor or canvas to dry. After the grain is dry enough to run readily through a drill, it may be sown at once, or it may be more thoroughly dried and then stored for sowing later.

The modified hot-water treatment as used for the control of the loose smut of wheat also kills the nematodes in the galls. This treatment consists of soaking the grain in water at room temperature for 4 to 6 hours and then in hot water at 129° F. for 10 minutes. The seed is then dipped in cold water and spread out in a thin layer to dry.

Clean Soil

Fields that have produced a nematode-infested crop should not be sown to wheat or rye for at least one year. Field experiments have shown that the absence of such susceptible crops from the land for one year will starve the nematodes in moist soil. In soil that receives no rain or other moisture, the nematodes may survive inside the galls in a dormant state for an indefinite period. Moisture is needed to soften the galls and reactivate the nematodes so that they can escape from the galls into the soil and invade susceptible plants.

Oats and barley are practically immune from attack, and may follow wheat in the rotation.

Infested straw or infested manure and litter should not be spread on land that is to be sown to wheat or rye unless it has been thoroughly rotted. The same holds true of stable manure from animals that have been bedded with straw from diseased grain. Experiments have shown that very few, if any, nematodes survive either passage through the alimentary tract of farm animals or prolonged decay in a manure pile.

Resistant Varieties

Numerous wheat varieties have been tested for resistance to the nematode disease, and only one variety, Kanred, has shown any appreciable degree of resistance. This variety, a hard red winter wheat, is not adapted to the southeastern United States.

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